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16. ABSTRACT

This manual is the third in a series of five that were developed to assist the highway engineer in determining impacts on the aquatic environment from proposed public works projects. This particular manual briefly discusses the legal requirements for environmental studies and water quality phenomena with relation to planning, designing, constructing, and operating a transportation system. The subject matter contained in the other manuals is tied together and discussed in terms of a coherent method for analyzing and reporting highway impact on water quality.

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WATER QUALITY MANUAL

A METHOD FOR ANALYZING AND REPORTING HIGHWAY IMPACT ON WATER QUALITY

EARL C. SHIRLEY
Supervising Air Pollution Research Specialist

RICHARD B. HOWELL
Associate Materials and Research Engineer

JOHN B. SKOG
Supervising Materials and Research Engineer
Environmental Improvement

JOHN L. BEATON
Chief, Transportation Laboratory

FOREWORD

A number of studies must be completed prior to the writing of an environmental impact statement for a highway project. One of these is a water quality study. This manual is the third in a series of five manuals compiled to assist the Districts in accomplishing this task with respect to water quality. It is intended to promote a uniform method for analyzing and reporting highway impact on water quality.

The titles of the five manuals in this series are as follows:

1. Environmental Analysis of Water Quality for Highway Projects

2. Glossary

3. A Method for Analyzing and Reporting Highway Impact on Water Quality

4. Highway Slope Erosion Transect Surveys

5. Chemical, Biological and Aquatic Ecosystems Analysis of Water from Highway Sources for Environmental Impact Studies.

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INTRODUCTION

The modern transportation engineer, in addition to his historic responsibility for planning, designing, building, and operating a transportation system, has become increasingly concerned with the amenities surrounding such a system. Foremost among these amenities are safety, aesthetics, and environmental protection. This manual, and those in the series associated with it, are directed at one aspect of environmental protection, namely that of water quality.

Changes in water quality caused by transportation systems occur mainly in the form of sediment from the land disturbing activities associated with construction of the system. Chemical and biological pollution also occur, although to a lesser extent. Hydrologic changes inevitably occur. Effects on the downstream user depend upon the use made of the water and vary from the loss of aesthetic appeal to damage to elements of the aquatic ecosystem.

The engineer, in responding to the need for environmental protection, is motivated by several forces. The first to make an appearance was in the form of a change in public priorities. In certain areas, freeways were no longer welcome neighbors and pressure for environmental protection began to be exerted through neighborhood groups and environmental coalitions appearing at public hearings. The concerns of these groups were eventually expressed in public law, both Federal and State.

As the movement for environmental protection gained momentum, a driving force from within the profession began to make itself felt. This change began with those engineers who welcomed added public responsibility and regarded environmental protection as a logical expansion of a dynamic profession. Typically, those organizations who were acknowledged leaders in their respective fields were among the first to respond in this fashion.

The development of the series of manuals on water quality impact, of which this one is a part, reflects the professional concern of engineers in the California Division of Highways for protection of the aquatic environment. This particular manual briefly discusses the legal requirements for environmental studies and water quality phenomena with relation to planning, designing, constructing, and operating a transportation system. The manual then attempts to tie together the subject matter contained in the other manuals in the series. This subject matter is discussed in terms of, hopefully, a coherent method for analyzing and reporting highway impact on water quality.

The professional approach to environmental protection on the part of the transportation engineer requires study and analysis in several different areas of which water quality is only one. Water quality is, however, tied very closely to some of the other study areas, particularly those of natural environmental hazards and natural environmental resources.

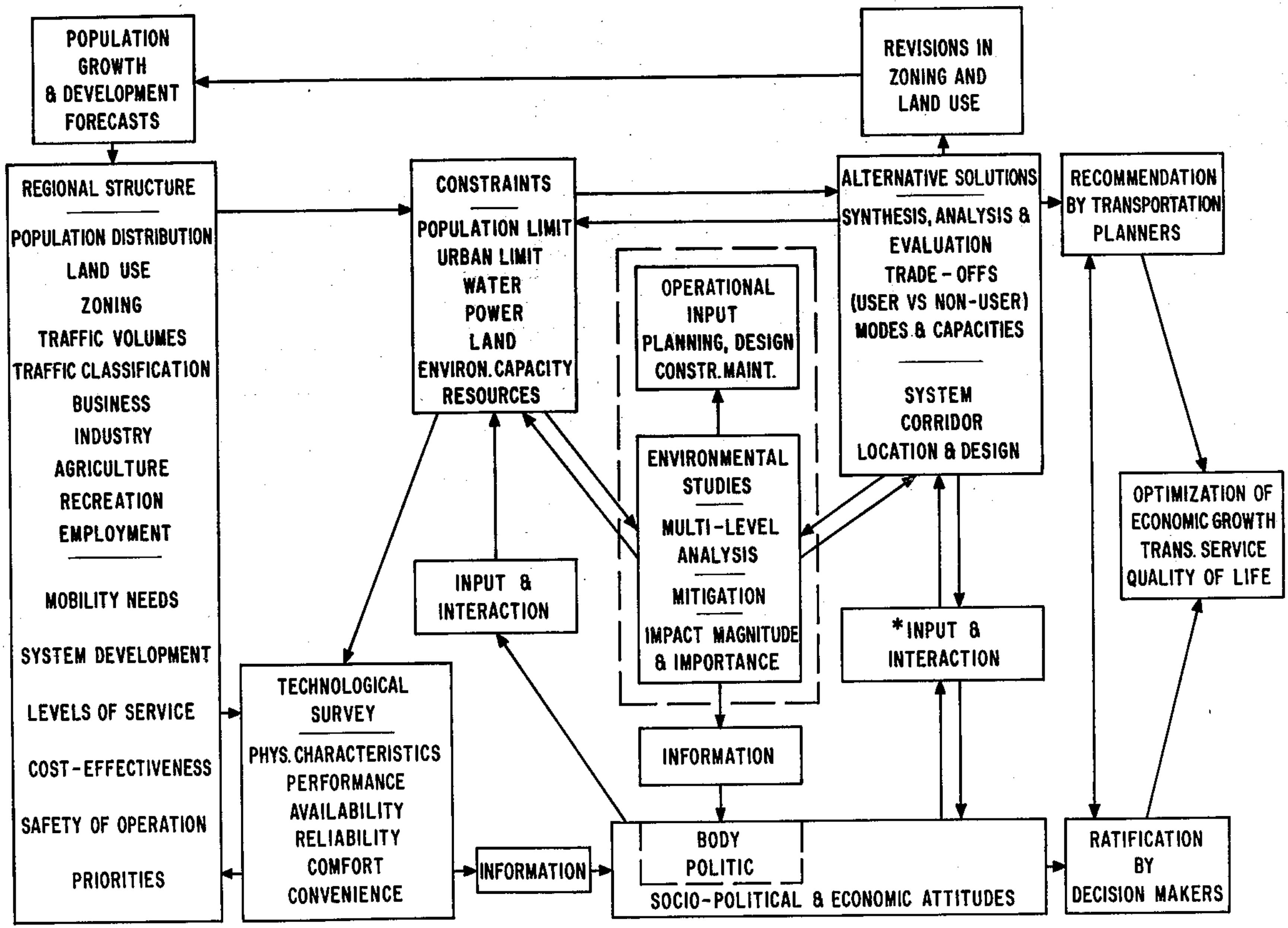
Environmental input to the transportation planning process is idealistically visualized in Figure 1. To assure that environmental input is fully considered and that the public is fully involved in the process and aware of the tradeoffs involved, the planning process, as we visualize it, must contain iterative and feedback mechanisms. Of particular importance is the feedback loop shown at the top of the diagram in Figure 1. This loop indicates that certain revisions in land use and zoning may be necessary to restrict or direct population growth and regional development commensurate with acceptable transportation solutions. This particular loop changes the planning process from one of reaction to one of action.

The environmental study block, surrounded with a dashed line in the center of Figure 1, is more fully developed in Figure 2. In Figure 2, the blocks forming a column on the left hand side spell out nine study areas required to complete a suitable environmental analysis. The center area of that figure denotes a two-stage analysis which provides broad scale environmental input at the systems planning stage as well as defining environmental input in some detail at the location and design stage. The important products of the second level analysis are shown in the column on the right-hand side of the figure.

It must be stressed that, in a professional approach to the inclusion of environmental considerations in transportation planning, the environmental impact statement is only one of the products of the environmental analysis. Other products of equal or greater importance include the recommendation of mitigation measures to be undertaken during design, the issuance of construction guidelines and recommendations for control of the contractor's operations, and the establishment of operational guidelines and safeguards for incorporation into the maintenance program.

A continuing program of monitoring and evaluation is necessary to provide data by which the predictive analyses may be validated or adjusted and through which the adequacy of mitigation measures may be judged. Inherent in this approach is the establishment of baseline data which reflect the existing state of the system under study.

TRANSPORTATION PLANNING PROCESS WITH ENVIRONMENTAL INPUT



* Coordinator - catalyst planner

Bishop Et. Al. HRR 305 P.47

Fig. 1

ENVIRONMENTAL STUDIES FOR TRANSPORTATION PROJECTS

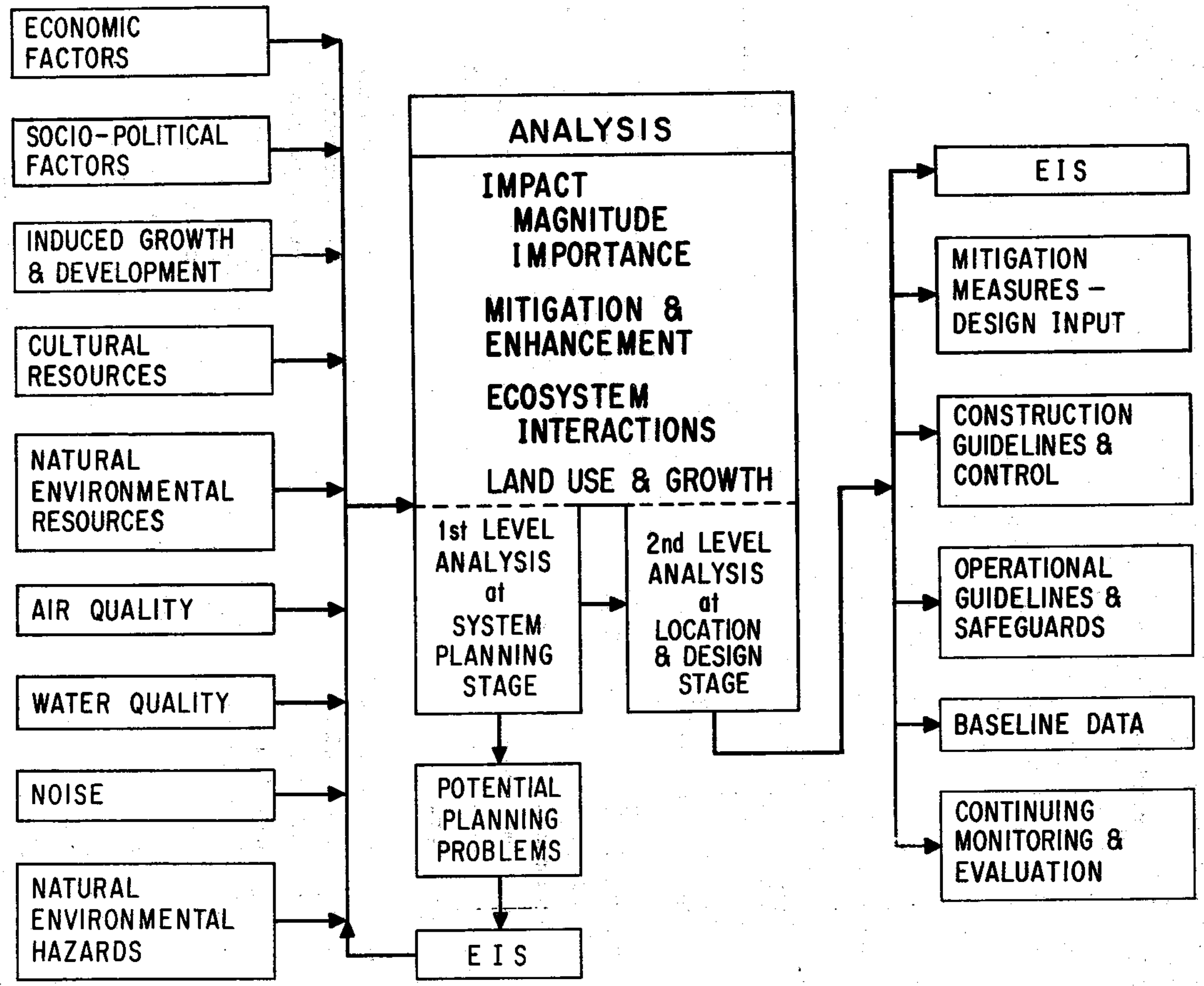


Fig. 2

LEGAL REQUIREMENTS FOR ENVIRONMENTAL STUDIES

It is important to understand the legal background for environmental studies since public law, in many cases, dictates the manner in which certain aspects of the study must be performed and, in general, dictates the questions which must be answered. Figure 3 shows the relationship between various State and Federal environmental laws and agencies concerned with water quality.

One of the major laws affecting the work of transportation agencies with regard to water pollution is the National Environmental Policy Act of 1969 (NEPA). This Policy Act proclaims a Federal policy to "encourage productive and enjoyable harmony between Man and his environment". This Act also formed the Council on Environmental Quality, to carry out this policy. Implementation of this Act by the Federal Highway Administration occurred in the form of Policy and Procedure Memorandum (PPM) 90-1. The purpose of this PPM is to provide guidelines to highway departments "to assure that the human environment is carefully considered and that national environmental goals are met when developing federally-financed highway improvements". This PPM reiterates that portion of the law requiring an environmental impact statement for each federally-financed project.

The Federal Aid Highway Act of 1970 provides for the establishment of general guidelines to assure that possible adverse economic, social, and environmental effects relating to any proposed project on any federal aid system have been fully considered in developing the project. Implementation of this Federal Highway Act has resulted in the issuance of various Policy and Procedure Memoranda (PPM) and various Instructional Memoranda (IM). Among other things, soil erosion guidelines called for by the act are provided in these memoranda.

Another important Federal law is the Federal Water Pollution Control Act of 1956 as modified through a series of amendments.

(particularly those of 1972-PL 92-500). The Act prescribes the development and enforcement of water quality standards. Individual states are required to establish levels of water quality according to the policies specified in the Act and to submit their plans to the EPA for approval. Once approved, the plans for water quality goals and objectives are implemented by the states.

On the State level, the California Environmental Quality Act of 1970 (CEQA), as amended, promotes the maintenance and enhancement of the quality of life. It requires that all State agencies, boards, and commissions shall provide for any project they propose to carry out which could have a significant effect on the environment of the State, a detailed environmental impact report. The State Act, in addition to reiterating the questions to be answered in an environmental impact statement for the National Act, requires a discussion of possible mitigation measures and an analysis of the growth inducing aspects of the project.

The State's Porter-Cologne Act, passed in 1969, established the State Water Resources Control Board and Regional Water Quality Control Boards. These latter regional boards are empowered to institute and enforce water quality objectives for drainage basins. The Water Resources Control Board is responsible for administration of the water quality plans and for the issuance and enforcement of permits for discharges.

Regional commissions and other regulatory agencies also provide guidelines and rules governing the discharge of wastes including those from construction activities. The State Department of Health is responsible for the safety of the general public regarding drinking water and public use waters. Enforcement of drinking water standards is accomplished through a rigid sampling and testing program of drinking water treatment plants and sewage disposal facilities.

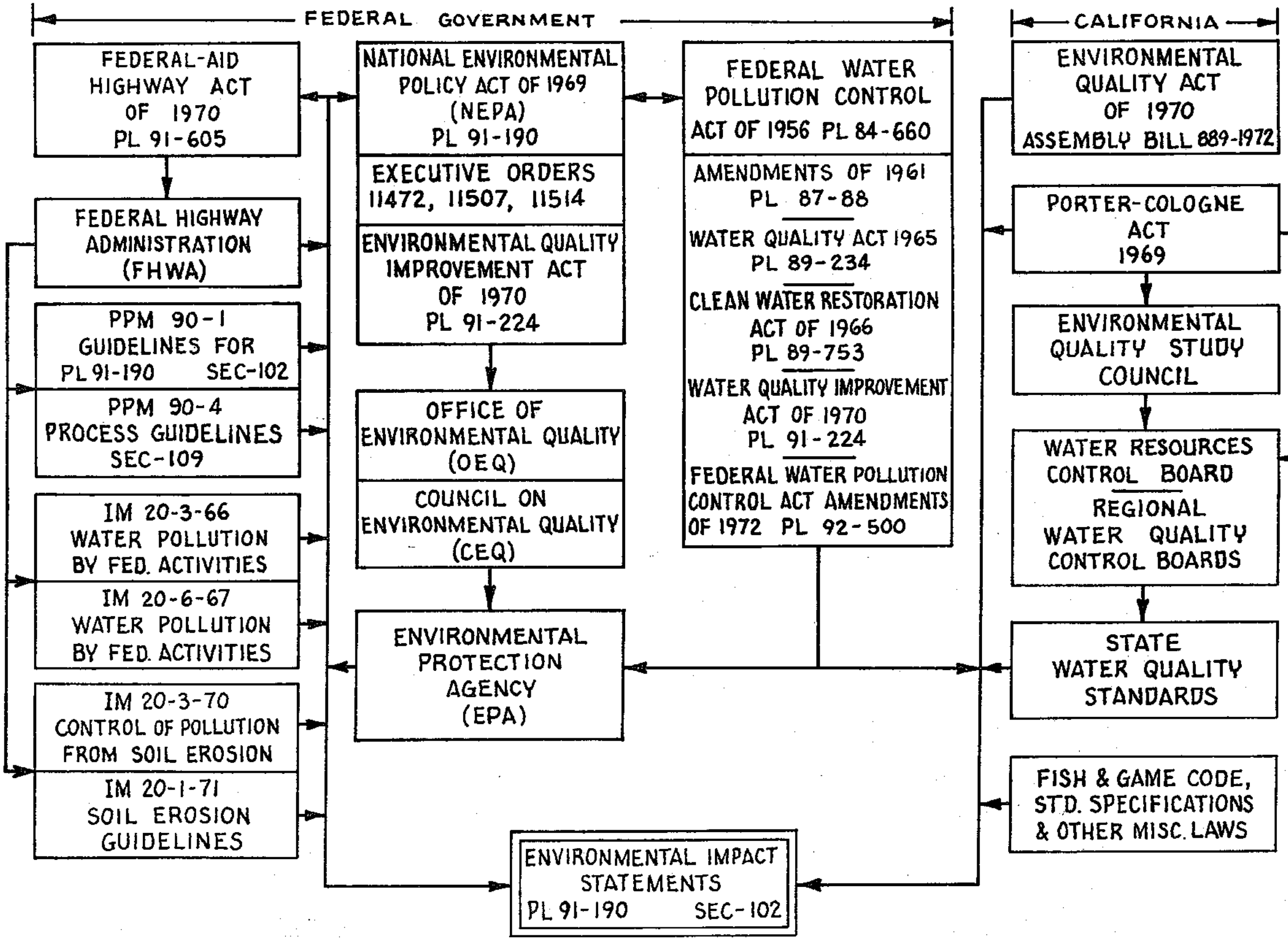
The Regional Coastal Commissions, Bay Conservation and Development Commission, Tahoe Regional Planning Agency, etc., are still further examples of regionalized government that may establish and enforce water quality regulations for such activities as road building.

The State Department of Fish and Game is particularly cognizant of the relationships between highway activities and wildlife. The Fish and Game Code specifies criteria necessary to protect and enchance fishery and other game resources.

The environmental impact statements required by the National Environmental Policy Act of 1969 and the State Environmental Quality Act of 1970 are disclosure documents. The statements should quantitatively examine the full range of impacts of the proposed action. A listing of the full range of impacts involved in a typical transportation project will ensure that critical impacts are not overlooked and will enable the early accurate identification of major environmentally significant actions. The impact statement should provide a basis for evaluation of the benefits of the proposed project in the light of its environmental risks. It should also enable comparison of the net balance for the proposed project with the environmental risk presented by alternative courses of action. It is essential that the statement quantitatively examine all positive and negative environmental implications of the project. The environmental impact statement should thus alert the decision maker as well as the public to the nature of the interests that are being served at the expense of environmental values.

Mr. William Riley, of the staff of the Council on Environmental Quality, feels that the environmental statement has three essential functions[1]. First, it results in the Executive, Legislative, and Judicial Branches of the Government scrutinizing the attention given to environmental aspects of federal agency decision making. Second, the statement helps an agency to define available options in terms of specific environmental impact in addition to technical

MAJOR LAWS & REGULATIONS GOVERNING WATER QUALITY IMPACT STUDIES FOR HIGHWAY PROJECTS



Fi. 3

and economic considerations. The third function is that of policy guidance.

Reasonable alternatives to the project must be considered in the environmental impact statement. One of these alternatives, of course, is that of taking no action at all. At the system planning stage, alternatives to be considered would include those of a significantly different nature which would provide similar benefits with different environmental impacts. For transportation projects, this might mean highways versus mass transport systems or differences between several proposed transportation corridor locations. At the location and design stage, the alternatives would be related to different designs or locations or details of the proposed action which might present different environmental impacts. In each case, the analysis of alternatives should be sufficiently detailed and rigorous to permit independent and comparative evaluation of the benefits, costs, and environmental risks of the proposed action and each alternative. Since water quality is one of the major study areas for assessing the environmental impact of transportation systems, the comprehensive water quality study should provide sufficient input to the writer of the environmental impact statement to enable him to answer the questions listed below concerning the impact of the project on the aquatic environment. This should provide an indication not only of the magnitude of the water quality impact but also some idea as to the importance of this impact [2].

1) What is the anticipated impact on water quality if the proposed transportation facility were built? <u>If not built?</u>

   Both positive and negative impacts should be identified. Both primary and secondary significant consequences for the environment should be included in this analysis. The relationship of the project to downstream receiving waters should be discussed quantitatively.

2) What adverse effects on water quality could not be avoided if the proposed transportation facility were built? <u>If not built?</u>

This question requires quantification so that damage to life systems, threats to health, or other consequences adverse to the environmental goals of the National Environmental Policy Act of 1969 can be fully assessed.

3) How would the relationship between local short-term uses of the water resource and the maintenance and enhancement of long-term productivity be affected if the transportation facility were built? <u>If not built?</u>

This requires an assessment of the cumulative and long-term impact of the proposed action on the aquatic environment with the view that each generation is a trustee of the environment for succeeding generations. The idea behind this question is the real substance of NEPA in that it intimates an extension of man's ethics, or social conscience, from people to natural resources. The question presupposes, on the part of the professional engineer, the development of a land ethic [3, 4].

4) What irreversible and irretrievable commitments of the water resource would be involved if the transportation facility were built? <u>If not built?</u>

The answer to this question involves identification of the extent to which the proposed improvement would permanently curtail the range of beneficial uses of the aquatic environment. In this sense, possible future uses of the water resource must be examined.

5) What mitigation measures could be implemented to minimize the impact if the transportation facility were built?

The answer to this question requires the description of mitigation measures which are normally undertaken to offset adverse impact. Most of these measures would normally be encompassed in design of the project and would be implemented during construction and maintenance.

6) Is the project consistent with the attainment of the water quality standards proposed for the basin?

7) To what extent would community growth be enhanced if the proposed transportation facility were built? If not built? How would this affect local water quality?

This question, directed at the growth inducing aspects of the project, must be considered in the light of the community master plan and expressed desires for community development by community leaders. The historical tendency of community leaders to either abide by or override the area master plan, as well as the temper of the community with respect to growth, must be subjectively analyzed. Local planning agencies must be consulted and should be able to provide the best estimates obtainable. The answer to the question must be made in terms of the effect, if any, of enhanced growth on water quality. This effect will not be related, physically, to the construction or use of the Transportation Facility. It will be related, however, to the increased demand on other uses of water caused by possible community growth resulting from building the Transportation Facility.

REFLECTIONS ON THE HYDROLOGIC CYCLE

Before looking closely at the subject of transportation projects and their impact on water quality, it is necessary to look at the precipitation phase of the hydrologic cycle to better understand the physical effects of our activities upon hydrologic processes.

Fate of Precipitation

Each raindrop or snowflake has a finite number of possible fates when it hits the earth. It may accumulate on the surface of the earth, it may run off of the surface, it may infiltrate into the ground, or it may evaporate or be transpired by a plant [5].

Surface accumulation occurs in ponds, lakes, marshes, and wetlands. The environmental attributes of ponds and lakes are fairly obvious to most people and are usually seen to consist of aesthetic features, homes for wildlife and fish, and opportunities for recreation. The environmental attributes of marshes and wetlands, on the other hand, are not so easy to perceive. This type of surface water accumulation is very important from a water quality standpoint, however, in that marshes and wetlands absorb nutrients, serve as areas of still water where sediment can drop out, oxygenate water, and assist waste decomposition. In addition, these areas act as "seed" sources for aquatic biota and serve to replenish these biota in connecting watercourses following natural or man-made catastrophes [6]. Wildlife is also conserved in these areas due to the relative inaccessibility of the area. The Suisun Marsh in the northeast part of San Francisco Bay plays a major habitat role for waterfowl of the Pacific Flyway.

Surface runoff starts in the form of overland flow and eventually becomes channel flow. Channel flow in the smaller watercourses such as streams can be either ephemeral or perennial in nature. Channel flow is almost always perennial in the larger watercourses such as rivers. During periods of large stream discharges, floodplains frequently become inundated. The floodplains are a necessary part of the channel regime and should be carefully considered during the design and construction of transportation facilities that encroach upon them.

Infiltration of precipitation maintains the groundwater resource which is, of course, the primary source of drinking water. Infiltrating water may wind up in an aquifer which may conduct it from one place to another or it may end up as part of the general water table.

Evaporation occurs wherever water is at the earth's surface. It occurs to a greater, or lesser degree depending upon climatic conditions. Transpiration occurs as a result of the use of water by vegetation in their life processes. It is highly dependent upon the type and areal extent of the vegetative cover.

Interfering Activities

The process of building and operating a transportation facility interferes with the processes listed above in various ways. Removal of vegetation for construction of the facility affects the process of transpiration and also influences the nature of overland flow. The building of embankments may compress aquifers and thereby either reduce the flow through the aquifer or perhaps stop the flow altogether, in which case a buildup of water pressure behind the embankment may occur. Embankments may prevent or channelize over-bank flood flow. Where embankments are constructed into a river, reservoir, or lake they create a loss of storage which is a function of the volume of the fill placed beneath the water surface. Embankments through marshes redirect the natural flow of water. Roadside ditches at the foot of embankments may cause drainage of marshes and wetlands.

Depending upon the location, cuts may intersect and drain aquifers or perched water tables. When the process of slope stabilization includes drainage of the soil mass, the water table may be greatly affected. Removal of materials from borrow pits as well as construction of embankments may afford opportunities for ponding of water. The ponded water may then increase infiltration into the ground and in turn increase the quantity of water flowing into an aquifer or raise the local water table. Channel changes can affect velocity of flow and upset the existing channel equilibrium. This is particularly true where a channel liner or riprap may be used which changes the friction factor for channel flow or where the relationship between slope length and gradient is altered.

Gathering surface runoff from the highway and its appurtenances and concentrating that runoff into a downdrain or other hydraulic facility and discharging that concentrated runoff at a point on a slope or into a stream channel may significantly change velocity and discharge quantity with subsequent changes in stream regime and erosion. It is interesting to note that few minor drainage facilities are designed using sediment transport considerations. The result is frequent high maintenance costs.

The impermeable surface created by paving the highway and the shoulders causes a substantial increase in the volume and rate of surface runoff. The use of long open conduits, such as ditches and trenches, to conduct water from one point on the highway to another creates a possibility for increased evaporation. Installation of piling and the drilling of test holes to examine foundation conditions may create a possibility for interconnecting aquifers and water tables.

WATER QUALITY PHENOMENA

Changes to aquatic systems resulting from the impact of transportation projects occur in the form of physical, chemical, and biological pollution and in alterations to the physical equilibrium of the system involving such parameters as temperature, flow, and boundary conditions.

Effects of these changes are exhibited primarily in water quality, the aesthetic appearance of the aquatic system, and the structure and form of the aquatic ecosystem. Most of these changes are felt both locally and by the downstream user. The downstream effect of changed water quality varies with the use made of the water, whether it be household, agricultural, industrial, or recreational. It is possible, in the case of some changes in the physical equilibrium, to affect upstream and downstream flow and boundary conditions.

Physical Aspects

In general, the greatest and most easily understood impact to aquatic systems caused by transportation projects is that of siltation of the systems. This occurs due to the erosion from freshly exposed and disturbed land surfaces with subsequent transport towards the stream by overland flow and downstream sediment transport to the point where the final impact is felt.

A less apparent impact, also falling under the heading, Physical Aspects, concerns the alteration of the physical equilibrium of the system. The removal of vegetation, for instance, sets into effect a chain of events beginning with lessened cover and a dead root system which leads to erosion, which in turn, due to the increased stream turbidity, reduces light penetration which inhibits the process of photosynthesis occurring in the stream. This means less food for aquatic organisms and causes a reduction in the numbers of these organisms in the aquatic ecosystem. At this point the aquatic ecosystem undergoes changes in its structure.

The removal of vegetation can also lead to a temperature rise which may completely inhibit those life forms with narrow temperature tolerance bands. In one notable case in Oregon, clear-cut logging raised the maximum annual temperature in a small watershed from 57° F to 85° F[7].

In channelization projects where the length of the channel may be shortened, the gradient is also altered. This causes the stream to seek a new equilibrium and upstream scour occurs until equilibrium is re-established. The erosion products, of course, are deposited in the downstream reaches.

In streams used by migrating fish, culverts designed without this use in mind can form effective barriers to migration.

Channel deepening can cause changes in the equilibrium conditions of shallow aquifers and also the resident aquatic ecosystems. The deepening can cause the drainage of wetlands and, if soils of different permeability are encountered by the deepening, can make intermittent streams out of previously perennial streams.

The provision of channels through wetlands in the form of road-side ditches can decrease the retention time of the waters in the wetlands. This in turn can cause a decrease in the cleansing action which occurs during the residence time of the water in the marshes and thereby lead to a decreased water quality in the water flowing out of the marsh area.

The use of stream beds for material sources may produce large excavations in the bottom which in turn lead to upstream erosion and in some cases, depending upon the flow characteristics in the stream, lead to areas of stagnant water due to inadequate mixing with the water flowing downstream.

The installation of riprap along a stream bank usually involves steepening the natural slope of the bank. In many cases, this may remove a large portion of the littoral zone where light penetrates and food production takes place. Depending upon the degree of turbidity, the shallow waters are usually the areas where most food production takes place. Also, the friction factor for riprap is normally different than that for the native channel and consequently the river will seek a new hydraulic equilibrium.

Most channelization projects create a rather homogenous aquatic environment from the standpoint of the aquatic ecosystem. The homogenous environment is not conducive to diversity in the ecosystem. Diversity in the ecosystem is a healthy condition and results from the variety of habitats provided by a natural aquatic system. That is to say, each organism has its own preference with regard to depth of water, velocity of flow, water temperature, availability of light, and availability of cover. Therefore, the more varied the conditions in the aquatic environment, the more varied will be the aquatic biota.

Chemical Aspects

Chemical water pollution occurring from transportation projects results from the use of deicing salts in cold areas, pesticides for control of noxious weeds and insect pests, soil sterilants, and fertilizers. Chemical pollution can also occur from such things as lead salt particulates from exhaust systems, and the various petroleum products used in and about the automobile. Accidental chemical spills involving tank trucks are of considerable concern where environmentally sensitive watersheds such as drinking water supplies are involved.

One of the more important and least understood aspects of chemical pollution is closely associated with erosion. This is the leaching and transportation of soil nutrients, toxicants, and trace elements into aquatic systems.

Biological Aspects

The possibilities for biological pollution occurring as a result of transportation facilities are rather limited. The principal activities leading to this sort of pollution occur in the disposal of human wastes at rest stops and similar facilities, the disposal of solid wastes found in roadside trash collection receptacles, and the disposal of animal carcasses by highways maintenance crews.

EFFECTS OF ALTERED WATER QUALITY AND HYDROLOGY

It can be seen that the effects of water pollution and alteration of physical equilibrium in the aquatic system are reflected in the structure of the aquatic ecosystem, aesthetic appeal of the aquatic system, the physical boundaries of the aquatic system, and in the continued acceptability of certain downstream uses of the water.

The aquatic ecosystem suffers from physical pollution in the sense that: increased turbidity means less light which in turn means less food production as mentioned above, silt deposition may damage certain aquatic life forms and change the character of the stream bed making it unsuitable for fish spawning grounds and activities of other aquatic biota, and may in the final receiving waters, increase the eutrophication rate by creating shallow, delta areas and carrying in nutrients which tend to attach themselves to sediment particles.

Chemical pollution may impact the ecosystem directly by poisoning aquatic biota and indirectly by triggering or stimulating the assimilation of nutrients by algae and phytoplankton thereby increasing the eutrophication rate. Biological pollution may contribute pathogenic bacteria to the water and may increase the rate of eutrophication within the ecosystem as well.

The primary aesthetic impact resulting from physical pollution occurs in the form of turbidity which masks the clarity and color which are so appealing to the human senses. Anything which increases the eutrophication rate of a water system is also a detriment to the aesthetic appeal. Biological pollution may also affect the senses through odor.

The physical boundaries of the system can be affected through the deposition of sediment on the one hand and erosion on the other hand. Capacities of lakes and reservoirs can be reduced by sediment deposition as can the capacity of streams and rivers. Erosion can lead to changes in hydraulic equilibrium and decrease the amount of land surface available for other purposes. Other aspects of physical alteration of the system were mentioned above.

The nature of the downstream uses of water determines, to a large extent, the degree to which the impact is felt. Turbid water is less appealing for recreational use than is clear water. Treatment of contaminated water for industrial or public consumption may be economically unfeasible. Agricultural users, however, may be able to tolerate water with a very wide range of quality. Certain fish populations such as members of the family Cyprinidae (carp and minnows) can tolerate a much wider range of water quality than can members of the family Salmonidae (salmon and trout). The length of time over which concentrations of pollutants are sustained may determine the effect on aquatic biota. As an example, sustained low levels of dissolved oxygen or toxic substances could produce a more severe effect on an organism as compared with relatively short periods at higher levels of stress.

COMPONENT PARTS OF A WATER QUALITY STUDY

The degree to which a water quality study is undertaken will vary primarily depending on whether the study is made during the system planning stage or during the location and design stage. The approach presented here provides sufficient detail for a study during the location and design stage. The effort proposed can be scaled down and made more general for studies made during the planning period to provide input for consideration of all possible alternatives.

The diagram shown in Figure 4 outlines the essential elements of a water quality study for a public works project and shows their relationship to one another.

Planning the Water Quality Study

The extent to which the water quality data will be useful for predicting environmental impacts from the proposed action depends largely upon how well the study is planned. Proper planning will provide a comprehensive survey that will yield sufficient data and information to adequately examine the ramifications of the proposed project.

Four basic steps should be covered in the preliminary planning stage. These are: 1) Define the problem and state the objectives of the study, 2) determine the information available for the project area, 3) develop a tentative plan of study, and 4) determine a list of tentative constituents to be sampled and the sampling frequency.

The first step necessary to plan a study is that of problem definition and establishment of the objectives of the study. When the problem is clearly defined, the limits of the study can be set to provide the best mix of economy and thoroughness of attack. Establishing the objectives provides the project leader with a

PROCEDURE FOR ANALYZING HIGHWAY IMPACT ON WATER QUALITY

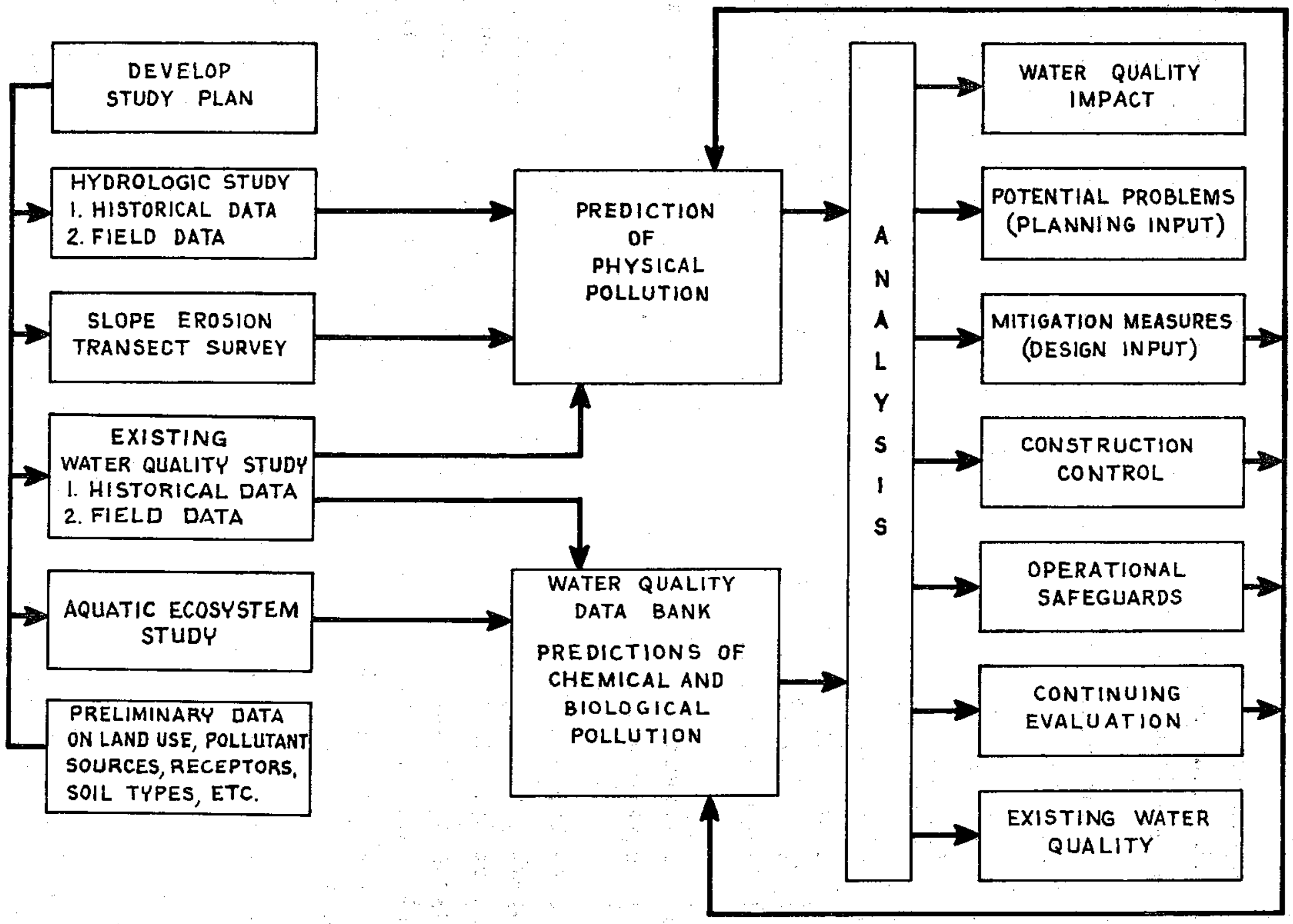


Fig. 4

framework for making high quality decisions with regard to sampling station location, sampling frequency, and water quality parameters to be examined. Typical objectives may include the following:

1) Determination of the natural water quality of the stream or lake.

2) Measurement of existing effects of discharges on a stream for a selected and limited time period.

3) Procurement of data on water quality and stream characteristics that will permit projection of the data to describe probable water quality and effects on uses under a variety of conditions other than those that prevailed during the study.

4) Determination of corrective measures needed to protect the stream water quality for proper uses.

The second step in planning any water quality study involves the assembly of all available knowledge into a format to assist planning the study. Once the available knowledge has been listed and examined it is then possible to develop sampling plans, locate sampling sites, and decide on sampling frequencies. The steps to be taken in planning the water quality study once the problem is defined and the objectives established, are listed below:

A) Using a suitable topographic map, plot:

   1) Watershed boundaries intersected by the project and the possible alternates,

   2) Lakes, ponds, marshes, wetlands, streams, rivers, and other surface aquatic features which are part of the affected watersheds,

   3) Springs, seeps, wells, and other indications of

groundwater,

4) Geological features affecting groundwater hydrology,

5) Locations of the existing or historical hydrologic data stations,

6) Locations of existing or historical water quality data stations,

7) Locations of historical ecosystem data,

8) Existing and future land use,

9) Existing and future sources of water pollution and their points of discharge,

10) Downstream water users (check water rights list), and passive receptors such as still water areas, estuaries, and confluences with larger streams,

11) Soil types with respect to erosion potential (possibly an overlay), contact other agencies,

12) Areas of surficial geologic activity such as landslides and soil creep, etc.,

13) Boundaries of plant associations or communities and associated microenvironmental conditions (possibly an overlay), contact other agencies,

14) Precipitation contours if data are available (possibly an overlay), contact other agencies,

15) Existing highways and old roads,

16) The proposed facility and alternates,

17) Cuts, fills, and other earthwork features along the proposed route and the alternates,

18) Other transportation facility features with a pollution potential, such as rest stops and areas where spills might cause problems.

B) Acquire historical data from 5, 6, and 7 above.

C) List the existing and potential future water uses.

D) Make a preliminary field survey or reconnaissance, including preliminary sampling, to fully develop the necessary information for the above items and for G and I below.

E) Review the appropriate water quality control guidelines and standards.

F) Select the water quality characteristics to be studied.

G) Locate sites for acquiring additional hydrologic and existing water quality data to supplement the acquired historical data.

H) Decide on the sampling frequency for each season.

I) Select existing slopes, typical of those to be constructed for the project, for slope erosion transect surveys.

J) Review the literature to develop a knowledge concerning previous studies and reports concerning water quality in the area. Sources for this information are educational institutions, private consulting firms, and quasi-public bodies such as irrigation districts, etc.

K) Modify the preliminary plans as indicated.

Briefly then, planning the study consists of several steps beginning with a definition of the problem and a statement of objectives, continuing through the compilation and display of existing knowledge in a format suitable for study, supplemented by preliminary field surveys, modification of plans as necessary, and culminating in a final plan which not only details the water quality data necessary, but also defines sampling locations and sampling frequencies. One necessary part of the planning process which is not detailed here is the matching of the sampling and testing program with available manpower and resources. In many cases this may prove to be the limiting factor and will, to a large extent, determine the sampling plan.

Field and Laboratory Work

The field work which should be undertaken in a water quality study consists of four elements: A hydrologic study, an existing water quality study, an aquatic ecosystem survey, and an erosion transect study. Although the studies involve separate areas of expertise, the studies should probably proceed concurrently in the field to insure the most efficient use of personnel.

The primary purpose of the hydrologic study is to provide a knowledge of hydrologic events that will enable a determination of sediment transport in the watershed. Typical elements of a hydrologic study include velocity, stage, precipitation, and the travel time, or concentration time, for various storm events. The details of a hydrologic study are given in the first manual in this series.

The existing water quality study serves several purposes in that it provides a baseline, so to speak, for existing water quality prior to the construction of a transportation facility, provides input to a water quality data bank for a given watershed, isolates the amount of pollution contributed by various sources along a watercourse by sampling above and below the source, provides an indication of the recovery properties of the watercourse by sampling linearly along the watercourse below a source of pollution and gives information concerning dilution and mixing characteristics of the stream.

An existing water quality study attempts to define physical aspects of water quality in the watershed in terms of sediment load, chemical properties in terms of certain elements and compounds, and the biological characteristics. The physical, chemical, and biological tests to be made on water are largely determined during the planning phase. Bacteriological organisms are normally examined only when the project includes a rest stop, maintenance installation, or other possible source of future biological contamination, except when the downstream water use involves a public water supply. In this case coliform count and other biological tests must be made. Exceptions may include stream courses that are currently affected by pollutants where the study objective is to describe ambient water quality conditions.

Another facet of the existing water quality study should include a close look at aquatic environmental factors. These factors determine the suitability of the stream for the maintenance of a viable ecosystem. Measurements to be made include water temperature, air temperature, pH, dissolved oxygen, toxicity, pesticides, nutrient load, total dissolved solids, alkalinity, and turbidity. A look should be taken at the vertical distribution of temperature and dissolved oxygen for bodies of water such as lakes and deep holes in streams and rivers to determine the existence of stratification and identify areas of low dissolved oxygen. In addition, notes should be taken on the physical character of the body of water or watercourse. The notes should include such items as depth, width, bottom description including shelter within the stream and shade or cover on the banks. The first manual in this series treats the existing water quality study.

The aquatic ecosystem survey serves three main purposes. The first purpose, of course, is similar to that of the existing water quality study in providing a baseline to define the existing aquatic ecosystem. Establishment of this baseline then provides a measure against which future changes in the ecosystem may be compared and evaluated. The second purpose for the survey lies in the fact that biota, whether aquatic or terrestrial, serve as indicators of environmental quality. In this manner, the very nature of the aquatic ecosystem in terms of the species present, their number, and their diversity, serves to define water quality. A third purpose for the survey lies in the fact that the aquatic ecosystem constitutes a natural resource and, as such, should be defined and quantified.

An aquatic ecosystem might be characterized as having zoological, botanical, and environmental elements. The zoological element could be characterized by the microfauna at or near the bottom of the food chain such as zooplankton and periphyton, the macrofauna in the middle, and the amphibians, fish, and associated mammals and birds at or near the top of the food chain. The botanical element would be comprised of the microflora such as phytoplankton and periphyton, aquatic plants, and the associated riparian vegetation. The environmental element, discussed on the previous page, is defined by such things as temperature, pH, dissolved oxygen, turbidity, alkalinity, and the nature of the system's physical boundaries (depth, width, bottom, etc.).

The aquatic ecosystem survey, for the purposes of this study, is divided into three parts: Macroinvertebrates, larger plants, and the amphibians, fish, and associated mammals and birds. Although this arrangement leaves- out the plankton and periphyton except for special circumstances, it gives a sufficiently large picture to allow assessment of the ecosystem.

Of these three subdivisions, the greatest effort should be expended on a study of the macroinvertebrates. Cairns, et al, lists several reasons for this [8]:

1) Benthic organisms are relatively sessile organisms and they cannot quickly avoid environmental stresses as fish often are able to do;

2) They have rather long and complex life histories and their presence or absence reflects the history of the environment;

3) Since they are members of the food web in an aquatic environment, their presence or absence directly effects fish populations;

4) Sampling techniques for bottom fauna are more reliable than techniques for fish; and

5) More biological information can be gained from studying this group of organisms per dollar invested than any other group.

The macroinvertebrates, or bottom macrofauna (benthos), are considered to be those that are retained on a number 30 sieve. Samples are taken upstream and downstream from the location of the proposed transportation improvement at locations which are comparable in terms of bottom conditions, depth, water velocity, stream width, and bank cover. The population of macroinvertebrates is examined in terms of diversity of species, density of individuals, and species composition. The most critical season for sampling is usually in the summer when the water temperature tends to be high and flow is relatively low. Samples from each season of the year are desirable. Yearly changes in stream bottom condition caused by hydrology and siltation must be considered. For analysis of temporal change in the ecosystem, it is essential to compare samples taken in the same season of the year, under similar slow characteristics, and under similar physical boundary conditions.

The sampling of amphibians, fish, mammals and birds should not be undertaken. Instead, their diversity and density should be estimated using observation and inductive techniques only.

The plant study can include the microflora (algae) although this requires highly trained people to identify the various species. The plant kingdom should be examined for diversity, density, species composition, and, in the case of the microflora, biomass and pigment concentration should be analyzed. The aquatic ecosystem survey will be treated in detail in the fifth manual in this series.

An erosion transect study serves to quantify the amount of erosion originating on existing cut slopes and embankments in the watershed. Study of existing slopes, which are similar to those slopes which will be exposed during the construction of the transportation facility, will allow reasonable estimates of erosion quantities to be expected from the new slopes. The slopes studied must be similar to those to be exposed in terms of soil type, degree of slope, and aspect of slope for valid extrapolation to the design situation. Manual No. 4 in this series treats in detail the method for highway slope erosion transect surveys.

Data Analysis

The analysis of data can be subdivided into four separate areas:

1) Existing water quality analyzed in terms of physical, chemical, and biological characteristics.

2) The existing aquatic ecosystem analyzed in terms of diversity, density and species composition of organisms and aquatic environmental factors.

3) Estimation of effect of changes in hydrology along the lines developed on Pages 16 through 18.

4) Estimation of water quality impact during the construction

period and during the operation period. The impact assessment during the construction period should include the physical aspects with the principal causes being the erosion of newly exposed soil and construction equipment operating in the water. This analysis will utilize the hydrologic study, sediment transport data, and slope erosion information. Chemical impacts during the construction period will consist primarily of oil and grease from equipment, and soil sterilization chemicals. The biological impact during a construction period should be analyzed primarily in terms of marginal sanitary facilities, which may be operated by the contractor. Also included in impact analysis for the construction period should be the contractor's use of solid waste disposal sites.

Water quality impacts during the operation period will consist of the physical impact caused by continuing erosion for which the hydrologic study, the sediment transport data, slope erosion transect study, and erosion control measures will provide input. The chemical impacts during the operation period will consist primarily of spills and maintenance usage of chemicals for snow and ice removal, pesticide control, soil sterilization, and fertilization. Other impact during this period should be analyzed in terms of rest area effluent, disposal of solid waste generated at rest areas and litter cans, disposal of animal carcasses, and the effect of street litter where the highway drainage system may pick up drainage from populated areas. In certain areas where the pavement surface is not washed regularly by rainfall and in large metropolitan areas, the effect of certain contaminants which tend to buildup on street surfaces may constitute the most important water quality impact.

DATA PRESENTATION

One of the most difficult aspects of any report on a study lies in the communication of the significant findings to other people. In the case of the water quality report, as in other environmental studies, the findings will probably be incorporated into an environmental impact statement by another person. This person may not be familiar with the technical procedures used in the water quality study. The statement he writes will then be used as a basis for decision making by still other people. Their knowledge will probably be of still lower order with regard to the technical aspects of water quality. Also it is very probable that the findings from the water quality study, in addition to being used in the environmental impact statement, will be used as a basis for discussions in a public hearing. Recommendations from the study will also be used to warn transportation planners of possible water quality hazards, alert the designer as to the need for mitigation measures, provide guidelines to construction personnel for control of the contractor's operations, and provide input to maintenance personnel for guidance during operation of the facility. It is, therefore, doubly important that the findings be communicated in a manner which promotes understanding and enables analysis by a reasonable layman.

It is also necessary to provide depth of technical detail to satisfy responsible reviewers of the water quality study who are desirous of ascertaining compliance with environmental law and assessing the validity of the conclusions with regard to the water quality impact.

It is entirely possible to address a report to several levels of understanding. The needs of the technically oriented person may be satisfied by presenting detail in the body of the report while the requirements of the reasonable layman, for a full understanding of the findings, may be realized with the aid of written, tabular, and graphic data summaries.

Statistical analysis of large quantities of data is desirable but it is important to understand the important aspects of each pollutant in order to properly describe the statistical data. For example, in a discussion of dissolved oxygen, a range of values over a 24-hour period has meaning whereas a mean value does not. Also, a one-way analysis of variance between data from an upstream and downstream station should be performed to determine if a significant difference does exist between the data or not. Hydrologic data should always be reported in terms of mean monthly flows or average annual yield or a range of flows.

WRITTEN AND TABULAR DATA SUMMARY

The following items should be presented in tabular form with sufficient written discussion for each item to fully explain the data:

1) Water quality should be shown in terms of chemical or biological characteristics and should be compared with the quality standards commensurate with the water use and with those promulgated by the Regional Water Quality Control Board. Existing, or baseline, water quality and predicted quality during the project life should be shown. A project life of 20 years should be used. The effect of probable changes in land use should be discussed for the project and its alternatives including the "no project" alternative.

2) Water quality data reflecting the physical aspects should be summarized in a manner that will show tonnages of sediment from the various project slopes and the nature of sediment transport for the various seasons of the year. Existing data should be shown and again predictions should be made for the assumed 20 year life of the project. Particular attention should be given to predictions during and immediately after the construction period since this is likely to be the most critical. Again comparisons should be made with water quality standards.

3) Changes in hydrology due to the various activities involved in constructing and operating the project, such as rainfall collection and concentration by the pavement and drainage appurtenances, changes in infiltration, and aquifer cutoff, etc., should be presented. That is, existing hydrology should be compared with predicted future hydrology and, again, the effect of changed land use that might result from building the

project or its alternatives, including the "no project" alternative, should be discussed in terms of alteration of existing hydrology. Where possible, the hydrologic changes should be quantified and, in all cases, a narrative discussion of the effect of the project on hydrology should be presented.

4) The results of the aquatic ecosystem study should be tabulated in terms of density, diversity, and species composition. The tabulation should be accompanied with a subjective discussion as to possible future alternations in the nature of the ecosystem which might be due to water quality changes associated with the project.

VISUAL AIDS

One of the best avenues of communication between the engineer and the layman is that which utilizes visual aids such as charts, graphs, and sketches. This approach, however, is often abused and fails to achieve its purpose due to the amount of detail on any one chart which the eye is required to assimilate. Simple visual aids, with minimal detail and the bold use of color, are the epitome of good communication. The principal use of the visual aid should be to present trends and comparisons. If the reader wants more detail, the tabular and written summaries, discussed previously, can be slightly more sophisticated from a technical standpoint. Even finer detail, of course, is provided within the body of the report.

Graphic presentation of trends, with time as the horizontal axis, can effectively demonstrate changes in pollutant concentrations, erosion and sediment transport. Acceptable levels of water quality for the various characteristics discussed can be presented graphically by using horizontal limit lines.

RESPONSE TO QUESTIONS FOR THE ENVIRONMENTAL IMPACT STATEMENT

The structure of the water quality report should take into account the fact that one of its primary purposes is to provide input to the writer of the environmental impact statement (EIS). In most cases, the EIS writer cannot possibly be technically competent in all the environmental study areas. This means that the individual study reports, such as the water quality report, must provide obvious, rather than hidden, answers to the questions to which the environmental impact statement must address itself. These questions were listed on Page 11 of this manual.

Answers to these questions must be quantified insofar as possible. This may be done for example by listing the changes in water quality in terms of tons per day of sediment or parts per million of other pollutants. The ultimate effect of water pollution, however, as it applies to human health, cannot possibly be estimated in a water quality study, but is rather the province of the epidemiologist.

Quantification of the changes in water quality, as indicated above gives an indication of the magnitude of the impact on specific sectors of the environment. This provides a rather objective indication of the degree, or scale, of the impact. Some indication of the importance of the impact should also be made. The importance, or significance, refers to the consequences of the change on the entire system. This is a subjective analysis and must necessarily be treated in a general narrative statement [2].

In the portion of the response dealing with the question on mitigation measures, the subject of enhancement should be brought forth. In many cases it will be possible to go beyond mere mitigation measures and actually provide an enhancement of the environment that previously did not exist. The enhancement should be discussed in detail.

REPORT AND FORMAT

The functions of a water quality report are:

(1) To describe existing water quality as a baseline against which future changes may be evaluated.

(2) To provide water quality input to the environmental impact statement.

(3) To provide planners with the means of incorporating water quality considerations in system planning, corridor selection, and location of transportation facilities.

(4) To enable the design of appropriate mitigation and enhancement measures.

(5) To provide guidelines for construction engineers in the evaluation and control of the contractor's operation.

(6) To provide guidelines for maintenance activities during operation of the facility.

(7) To recommend the nature and extent of a continuing program for control and evaluation during operation of the facility.

Report Format - Water Quality Study

The following outline is offered as suitable format in which to report a water quality study. It is not the intent of this manual that the format for a study should be rigid and inflexible. There are many cases in individual studies where the report writer will have to depart from the proposed format in order to provide a more meaningful report.

In general, a report on water quality study should contain the following subdivisions:

1) <u>Project Description</u>: This should be a short narrative statement of not more than a few paragraphs describing the proposed improvement and the alternatives in sufficient detail to provide the reviewer with a mental picture of the work to be done. It is also necessary in this project description to give the reader some indication as to the background behind the project so that he fully understands the context into which the project fits.

   A statement should be made as to time constraints and other conditions imposed upon the study. The objective of the study should be given.

2) <u>Conclusions</u>: The conclusions are presented early in the report. This allows the person who does not desire to dig through the detail to read the project description and the conclusions and thus obtain a cursory knowledge of the project. In the conclusions, the first thing to be discussed should be the answers to the questions for the environmental impact statement. Secondly, the findings, as they apply to the following headings: (a) potential problems in planning, (b) design mitigation and possible enhancement, (c) construction control, and (d) operational safeguards, should be presented briefly. The final portion of the conclusions should present the written and tabular data summaries as described above. These can be interspersed with graphic data presentations also described above.

   In this manner, the conclusions, in conjunction with the project description, enable the layman to understand the impact on water quality, provide the EIS writer with some basic answers to the water quality aspects of the questions he needs to answer, and provide transportation engineers, in the planning, design, construction, and maintenance areas, with warning flags marking areas which need further consideration.

3) <u>Background Discussion:</u> This section provides a background in terms of water quality data rather than a background of of the project itself. This section should provide a resume' of all the historical data that were researched for the study. These data should be presented under the following general topics:

a) Topography. Include a copy of the map discussed earlier in this manual delineating watersheds, streams, lakes, etc.

b) Historical hydrology.

c) Historical water quality.

d) Historical ecosystem data.

e) Existing sources of water discharges.

f) Existing and future land use.

g) Existing and future downstream water use.

h) Research of previous studies.

i) Results of discussion with other agencies.

j) Designated water quality standards.

4) <u>Description of Field Studies:</u> The field studies should be fully described including instrumentation used, calibration

of that instrumentation, dates and locations where observations were made and a discussion of the setups at the various points. This section should be divided into five sub-sections:

a) Preliminary field survey including erosion potential, geologic activity, plant association boundaries, study site location, and slope selection for erosion transect surveys.

b) Hydrologic study including data reduction and results.

c) Existing water quality study including data reduction and results (present as existing water quality).

d) Aquatic ecosystem survey including data reduction and results (present as existing ecosystem).

e) Erosion transect study including data reduction and results.

5) Data Bank Description: The data bank used to draw conclusions in the water quality study will consist of the historical data that were researched prior to and during the study and the data which were developed by the survey teams during the water quality study itself. In this section these data should be fully described as to source. For instance, sources of the historical data should be listed and sources of any data collected during the field surveys which come from other people than those involved in the study itself should be listed. The data bank description will be necessary to satisfy regulatory agency reviewers.

6) Water Quality Predictions: This section should be divided into five subsections as follows:

a) Physical contamination. This is largely an objective evaluation based on the results of the hydrologic study, the slope erosion transect survey and transport and sedimentation data. The predictive method should be described so the reviewer can see how the writer arrived at the results. Mitigation measures should be taken into account.

b) Chemical contamination. This evaluation will be largely subjective but it will be based upon the existing water quality study and a knowledge of past and future conditions. The evaluation will take into account, however, the mitigation measures proposed for the project.

c) Biological contamination. Again this is basically a subjective evaluation based on past knowledge of similar installations and future conditions. Mitigation measures will again be an input to this prediction.

d) hanges in hydrology. Although not strictly a water quality parameter, predictions must be made based on the analysis of the hydrologic study and a knowledge of the design features of the project. This change should be estimated and incorporated into the analysis for physical contamination as previously mentioned.

e) Changes to the aquatic ecosystem. This is another largely subjective evaluation based on past knowledge of similar installations and an estimate of the future aquatic environmental conditions. Mitigation measures should also be a part of this prediction.

7) Potential Problems: This input is essential to the planning process since it serves to identify possible planning hazards with respect to water quality. In this section the alternatives, including the "no project" alternative, can be compared with respect to the potential water quality problems they might create.

8) <u>Mitigation Measures</u>: This section serves as an input to the project design. It describes not only the permanent measures but also those temporary measures which can be foreseen as necessary during the construction process and should be encompassed by the project design. This is also the area where possible enhancement should be treated.

9) <u>Construction Control</u>: This section should fully develop and provide notice to the construction engineer of possible construction problems. It should also outline a series of control tests which could be used to evaluate the contractor's compliance with water quality agency regulations during the construction and with his own erosion control plan. This section should also provide information which will assist the resident engineer to evaluate the adequacy of the contractor's erosion control plan.

10) <u>Operational Safeguards</u>: A listing and discussion of possible problems during operation and maintenance of the project should be spelled out in order to provide input to maintenance engineers. This section includes such things as precautions for accidental, hazardous spills based on the downstream use of the water, precautions as to certain maintenance activities using pesticides and soil sterilants, etc. In the case of hazardous spills, maintenance should be called upon to develop a contingency plan for each sensitive drainage area listing procedures for discovery and notification, containment and counter measures, cleanup and disposal, and restoration.

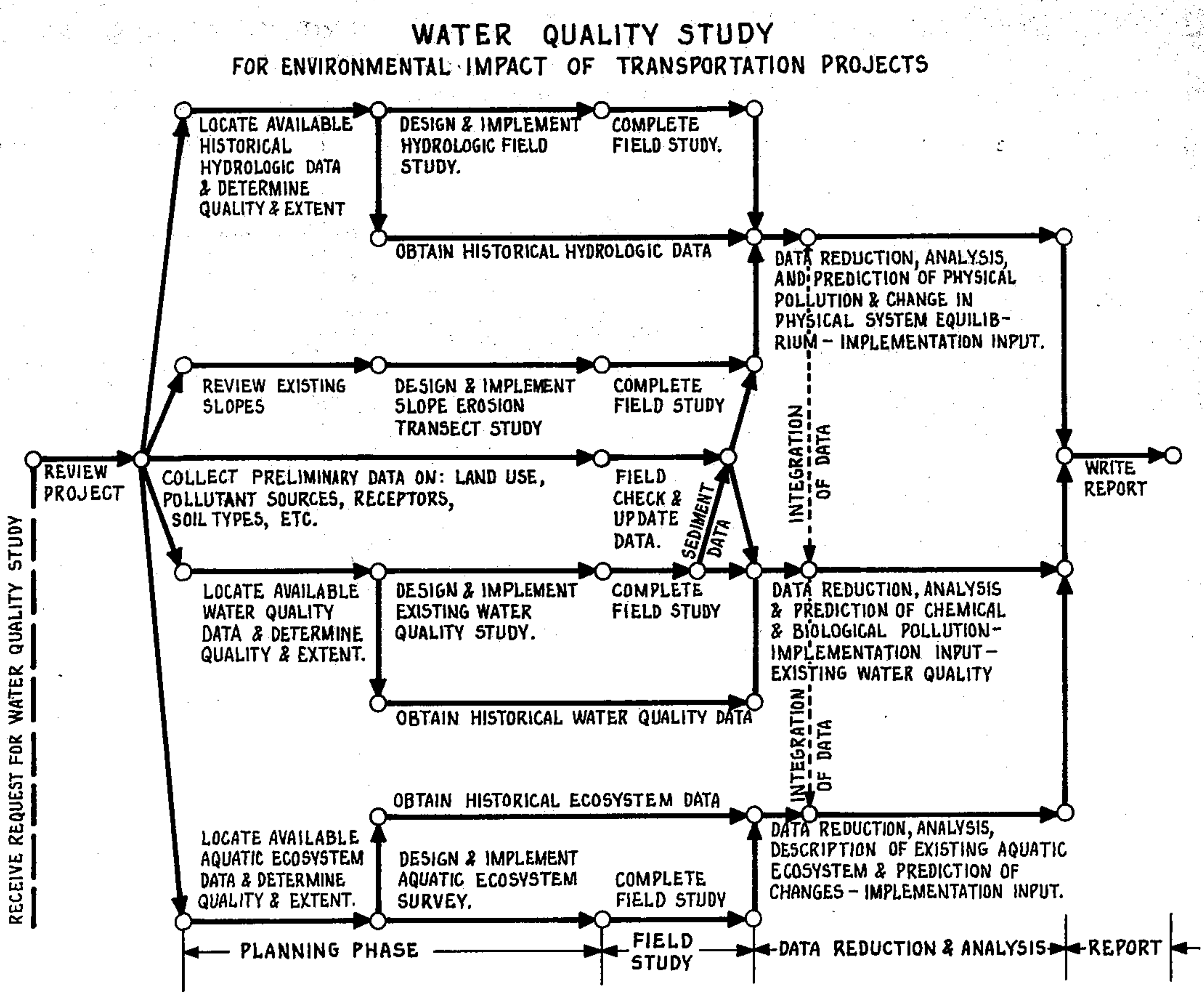
11) <u>Continuing Evaluation</u>: This section should prescribe the content of a long-term measurement program both to evaluate the accuracy of the predictive process and to evaluate the efficacy of the mitigation measures that were constructed.

This continuing evaluation, when used in conjunction with the water quality and ecosystem baselines described under 4c and d above, provides a closed loop for the water quality study.

12) <u>Bibliography:</u> In this section the sources of the historical data used in the report, sources for statements that may have been made, and references to the series of water quality manuals should be listed for the benefit of the reader. This section should not be confused with section five which is a description of the data bank. It is not intended that these sections duplicate each other.

13) <u>Appendices:</u> If desired, the reduced hydrologic and water quality data from the field studies may be attached to the report in appendix form. These appendices should be attached only to those reports going to interested agencies such as regional water quality boards and perhaps the Department of Public Health. The average reviewer will be interested only in the data summaries.

The work involved in a water quality study, from the planning of the study through the reporting phase, is shown in Figure 5. This diagram places the various elements of the work in a time perspective to show the interrelationships involved.



WATER QUALITY STUDY
FOR ENVIRONMENTAL IMPACT OF TRANSPORTATION PROJECTS
RECEIVE REQUEST FOR WATER QUALITY STUDY
REVIEW PROJECT
LOCATE AVAILABLE HISTORICAL HYDROLOGIC DATA & DETERMINE QUALITY & EXTENT
DESIGN & IMPLEMENT HYDROLOGIC FIELD STUDY.
COMPLETE FIELD STUDY.
OBTAIN HISTORICAL HYDROLOGIC DATA
DATA REDUCTION, ANALYSIS, AND PREDICTION OF PHYSICAL POLLUTION & CHANGE IN PHYSICAL SYSTEM EQUILIBRIUM - IMPLEMENTATION INPUT.
REVIEW EXISTING SLOPES
DESIGN & IMPLEMENT SLOPE EROSION TRANSECT STUDY
COMPLETE FIELD STUDY
COLLECT PRELIMINARY DATA ON: LAND USE, POLLUTANT SOURCES, RECEPTORS, SOIL TYPES, ETC.
FIELD CHECK & UPDATE DATA.
SEDIMENT DATA
INTEGRATION OF DATA
WRITE REPORT
LOCATE AVAILABLE WATER QUALITY DATA & DETERMINE QUALITY & EXTENT.
DESIGN & IMPLEMENT EXISTING WATER QUALITY STUDY.
COMPLETE FIELD STUDY
DATA REDUCTION, ANALYSIS & PREDICTION OF CHEMICAL & BIOLOGICAL POLLUTION-IMPLEMENTATION INPUT-EXISTING WATER QUALITY
OBTAIN HISTORICAL WATER QUALITY DATA
INTEGRATION OF DATA
OBTAIN HISTORICAL ECOSYSTEM DATA
LOCATE AVAILABLE AQUATIC ECOSYSTEM DATA & DETERMINE QUALITY & EXTENT.
DESIGN & IMPLEMENT AQUATIC ECOSYSTEM SURVEY.
COMPLETE FIELD STUDY
DATA REDUCTION, ANALYSIS, DESCRIPTION OF EXISTING AQUATIC ECOSYSTEM & PREDICTION OF CHANGES - IMPLEMENTATION INPUT.
PLANNING PHASE
FIELD STUDY
DATA REDUCTION & ANALYSIS
REPORT

Fig 5

THE WATER QUALITY DATA BANK

The California Department of Water Resources currently publishes water quality and hydrologic data annually in various bulletins. Most hydrologic information is published in conjunction with the U. S. Geological Survey. Through the U. S. Environmental Protection Agency, a nationwide data storage and retrieval system is being developed called STORET[9]. It is important for the districts to maintain a file system for recovery of data developed on stream surveys for use on future projects. Headquarters Transportation Laboratory will assist in the development of a system.

OUT-OF-HOUSE STUDIES

Variability in workload, complexity of the studies, and certain other factors may make it desirable to use a consultant in the performance of a water quality study. To facilitate the hiring of such a consultant, a request for proposal (RFP) has been developed. The study outlined in the RFP, in a different format than that shown in this manual, has been structured to allow the consultant a certain latitude in using his expertise to develop the best possible approach. The recommended form for a request for proposal is shown in Appendix A.

SYSTEMS APPROACH TO WATER QUALITY STUDIES

It would be desirable, as soon as possible, to go to an integrated systems approach for the analysis of transportation impact on the aquatic environment. If it were possible to develop an integrated transportation plan for an existing urban area, a water quality study could be made which could fully evaluate the interactions as the various parts of the transportation network were constructed and brought into the system. In the planning phase, it would be possible to bring water quality consideration into the decisions for the location of transportation corridors.

As a beginning, with the development of data banks in the Transportation districts, each district should begin to construct hazards maps. These maps would be informational aids to the transportation planner and would indicate areas having higher probabilities of erosion, poor water quality, water table problems, etc.

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APPENDIX A

*REQUEST FOR PROPOSALS FOR A WATER QUALITY STUDY

*A Hypothetical Request for Proposals is Given in This Example.

REQUEST FOR PROPOSAL

REASON FOR STUDY AND EXACT LOCATION

The Department of Transportation is required to prepare a report on the environmental impact of each proposed transportation project. One part of this report deals with the present and future effects on water quality.

The present need is for a water quality study which covers the proposed rerouting of Highway 50 between Twin Bridges and South Lake Tahoe. It is proposed that this project be analyzed by a private consultant for impact on water quality within the geographical region shown on the attached location and freeway strip map.

STUDY OBJECTIVES

In general, the study shall provide answers, quantified where possible, to the following questions:

1. What is the anticipated impact on water quality if the proposed transportation project were built? If not built?

2. What adverse effects on water quality could not be avoided if the proposed transportation project were built? If not built?

3. How would the relationship between local short-term uses of the water resource and the maintenance and enhancement of long-term productivity be affected if the transportation project were built? If not built?

4. What irrerversible and irretrievable commitments of the water resource would be involved if the transportation project were built? If not built?

5. What mitigation measures could be implemented to minimize the impact if the freeway were built?

6. Is the project consistent with the attainment of the water quality standards proposed for the drainage basins which will be affected?

7. What will be the effect of induced growth and development, related to the service life of the project, upon water quality within the area?

Answers to these questions shall consider demographic projections and land use patterns provided by local planning groups and agencies. For the "not built" case, close attention shall be paid to anticipated development and growth which might occur as a result of expansion of the existing surface street network.

Specifically, the study shall provide quantified solutions in the following areas:

1. Define existing water quality in terms of the physical, chemical, and biological quality parameters which may be applicable to the project.

2. Define the existing aquatic ecosystem in terms of its zoological, botanical, and physical environmental elements.

3. Predict changes, for the various project alternatives including the non-project alternatives, over a 20-year period beginning with the estimated time of completion of the facility for the following areas:

    a. water quality(physical, chemical, and biological)

    b. aquatic ecosystem(species composition, diversity, and density)

c. physical equilibrium (hydrology and boundary conditions)

The study shall also enable the incorporation of water quality considerations in the various functional areas of the transportation agency through the following actions:

1. Provide planners with sufficient information to allow consideration of water quality in system planning, corridor selection, and the location of transportation facilities within the project area.

2. Provide information to transportation facility designers to enable the inclusion of appropriate mitigation and enhancement measures in the design process.

3. Provide guidelines to construction engineers for the evaluation and control of the contractors operation.

4. Provide guidelines for maintenance activities during operation of the facility.

5. Recommend the nature and extent of a continuing program for monitoring and evaluation.

In the development of the work plan to satisfy the study objectives, particular attention shall be paid to the local, state, and federal water quality standards which apply in the project area.

SCOPE OF THE WORK

The study shall encompass a sufficient span of time and shall include a sufficient number of data points to insure statistically valid hydrologic and existing water quality data. Particular attention shall be paid to certain hydrologic regimes, especially those of low flow and high water temperature, and system boundary features which might tend to maximize pollutant concentrations or their effects. Fluctuations in water quality due to population pressure variations, such as weekend use of recreational areas, shall also be a matter of consideration.

Predictions of changes in water quality due to physical contamination with the products of erosion shall be based upon a collection of data broad enough to preclude bias which might occur from a short-term data collection. Particular attention shall be paid to that erosion expected during and shortly after the construction period and to the appropriate mitigation measures for that period. Guidelines for the evaluation of a contractor's erosion control plan shall be provided.

A program for the continued monitoring of the project so as to analyze the adequacy of the predictions and the performance of the mitigation measures shall be prescribed.

Field and laboratory studies of hydrology, sediment transport, and existing physical water pollution shall employ the equipment, methods, and techniques of the United States Geological Survey, as outlined in their manual series titled "Techniques of Water Resources Investigations of the United States Geological Survey". In particular the manuals entitled "Fluvial Sediment Concepts", "Field Methods for Measurement of Fluvial Sediment", and "Laboratory Theory and Methods for Sediment Analysis" shall be used.

Field and laboratory studies of the existing chemical and biological aspects of water quality shall utilize the methods, techniques, and tests outlined in the latest edition of "Standard Methods for the Examination of Water and Waste Water", prepared and published by the American Public Health Association, American Waterworks Association, and the Water Pollution Control Federation.

The paragraphs above do not preclude the use of other techniques, methods, and equipment to provide supplemental or alternate data. Alternates for the prescribed methods, however, must be fully qualified in the proposal.

The study of the aquatic ecosystem shall reflect the functions of the ecosystem both as a resource and also as a biological indication of water quality. The aquatic ecosystem shall be considered to consist of plankton, periphyton, macroinvertebrates, fish, and associated amphibians, mammals, and birds. Special attention shall be given to those organisms which serve as biological indicators. In most situations, the macroinvertebrates should receive the greater part of the study effort. Results of the study shall be interpreted in terms of the effects on the ecosystem.

All equipment shall be calibrated during the study at intervals which are sufficient to maintain desirable accuracy. Calibration records shall be maintained. The methods of calibration chosen shall bracket the ranges used in the study. Laboratory test methods and techniques shall be checked and verified through a correlation of a testing program with a well recognized and certified laboratory. A tentative work plan for the study, including the locations, type, and duration of observations should be furnished by the contractor in the proposal. It is expected that this will require an onsite study of the area prior to furnishing a proposal. The tentative work plan will be evaluated by the Department of Transportation staff and at least one water quality consultant.

Existing water quality data shall be collected at a sufficient number of sites to characterize pollutant levels in the watershed under study. Particular attention shall be paid to the existing discharges and to those watersheds with more sensitive downstream water uses. Use shall be made of existing data sources. Test locations chosen primarily on the basis of convenience will not be acceptable.

Demographic projections and changes in land use patterns shall be estimated based on existing available projections by local agencies. For comparison of transportation facility impact, the prediction of future pollutant levels with and without the project shall encompass a period beginning just prior to completion of the project and ending at a time 20 years subsequent to its completion.

Where the prediction of pollutant levels or stream hydrology is accomplished using mathematical modeling techniques, a consultant shall provide model validation. Where models are used, the sensitivity analysis of the model in terms of the data requirement is required in the proposal. This analysis should examine the relative influence of the input parameters in estimations of pollutant concentration.

The consultant shall deliver to the Department of Transportation all raw data and a copy of all mathematical model(s) employed along with the rationale used in development. If the model(s) are computerized, a punched card source deck and user instructions shall also be supplied.

A consultant shall prepare a report for the Department which presents comprehensive summaries of pertinent data and draws conclusions as to the impact of the proposed transportation facility upon water quality. The report shall also discuss the relationship of the project to the attainment of the regional water quality standards. The report shall contain graphs showing changes in water quality for the various alternatives, including the non-project alternative, over the time period specified. Any such graphs shall present a simple, clear, straightforward approach to data display and shall be suitable for use at a public presentation where local citizens may use them as a basis for discussion and decision making. Basis for the graphs shall be clearly outlined in the text. The report format shall conform to the following style:

1. Title Page

2. Abstract

3. Table of Contents

4. List of Figures

5. Notation (if necessary)

6. Introduction

7. Conclusions
   (In a form suitable for including in the project environmental impact statement. Should be easily understood by those not familiar with the technical aspects of water pollution and hydrology.)

8. Discussion
   (Objective of study, study plan, sampling and testing procedure, description of work, data analysis, equipment and calibration, etc.)

9. Bibliography

10. Appendix

A consultant may also be required to present his findings at one or more public hearings.

<u>TIME SCHEDULE</u>

Final Proposal Submittal Date (Four Copies Required)	December 1, 1973
Anticipated Contract Approval Date	Within 60 days after submittal deadline.
Commencement of Work	Within 15 days after notice of contract approval.

TIME SCHEDULE (Continued)

Submission of Progress Report	June 1, 1974
Completion Date	Twelve (12) months after contract approval.

BUDGETARY LIMITATIONS

Contract amount not to exceed $50,000.

PROPOSAL FORMAT

The prospective consultant shall include in his proposal the following items:

1. Description of his qualifications; list of similar types of consulting contracts successfully completed, with a sample of such work; brief descriptive resumes of the principal investigators and support personnel to be employed on the project; amount of time and manpower to be expended; description of equipment and facilities to be utilized; and, if subcontractors are contemplated, a description of these persons or firms and the portions and monetary percentages of the work to be done by them.

2. An overall description of the techniques by which solution of the problem will be approached and a tentative work plan.

3. Total cost of the study, a detailed breakdown of its computation showing actual rates and mark-ups, and the preferred method of payment.

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